Pre-Screen Loss of Chinook Salmon Juveniles Before and After Predator Reduction in the Primary Channel at the Tracy Fish Collection Facility (CA)

Investigator

Mark Bowen, Ph.D.
Fishery Biologist
Fisheries and Wildlife Resources Group
US Bureau of Reclamation
Denver Technical Service Center
Denver, CO 80225
mbowen@usbr.gov

Introduction

The Tracy Fish Collection Facility (TFCF) salvages Chinook salmon (*Oncorhynchus tshawytscha*) juveniles before they are entrained into the Delta-Mendota Canal and are lost from the Sacramento-San Joaquin Delta ecosystem. Here I propose to investigate what the National Marine Fisheries Service (NMFS) terms "Pre-Screen Loss" (PSL: proportion of fish that do not successfully pass from the trashrack to the primary louver array), and whole facility efficiency (WFE) for Chinook salmon juveniles. In addition, to meet NMFS (2009) biological opinion's Reasonable and Prudent Alternative Action IV.4.1.a., I will conduct a PSL estimate, and then remove predators from the primary channel. Following predator removal, I will again estimate PSL to determine if the predator removal has reduced "pre-screen predation in the primary channel" (NMFS 2009) to less than 10%.

Many fish species are affected but the U.S. Department of the Interior/Bureau of Reclamation (Reclamation) does not have the resources to study them all at the same time. Thus, I selected a target species of economic, cultural, and ecological importance: Chinook salmon. I will focus this work on Chinook salmon juveniles migrating downstream to the ocean because methodologies to acquire fish, hold them, surgically implant them, and release them are well developed (SJRGA 2010, Adams *et al*. 1998; Martinelli *et al*. 1998). In addition, Kimmerer (2008) has shown that the diversion facilities can have a population level effect on Chinook salmon numbers.

This proposal is based, in part, upon the work of Bark *et al.* (In Preparation). Bark *et al.* showed the telemetered striped bass they studied remained in the TFCF an average of 73.1 d. The observed fates for the telemetered striped bass they studied included: (1) for fish small enough to pass through the trashrack a large proportion moved up and out of the TFCF and (2) for larger fish, they were salvaged, moved downstream through the primary louver array presumably during cleaning, or were removed by gillnet from the primary channel. Regardless of the ultimate fate, most striped bass studied appeared to become resident in the TFCF for long periods in the primary and secondary louver channels. Due to this long residence time in the TFCF, because striped bass are known to prey upon Chinook, and because they occur in large numbers (unpublished DIDSON observations) in the TFCF, I selected striped bass as the

target predator. I intend to surgically implant 20 long-lived acoustic transmitters in striped bass and track them as the telemetered Chinook navigate the TFCF.

The fish salvage at the Tracy Fish Collection Facility (TFCF) is accomplished in two louver channels. The primary channel has a maximum depth of 6 m (20 ft) and is completely traversed by the primary louver array which is 97.5 m (320 ft) in length and 25.6 m (84 ft) in width. The louver array is angled 15° to the channel and has four bypasses. Each bypass is 15.3 cm (6 in) wide and leads to a primary bypass pipe 91.4 cm (36 in) in diameter. These four pipes deliver water to the secondary louver channel.

This large primary area hosts a large number of large piscivores (unpublished DIDSON observations). I hypothesize that these predators can be an important source of Chinook salmon loss in the primary channel. Indeed, striped bass may be an important source of Chinook salmon loss throughout the entire TFCF.

The secondary louver channel has a maximum depth of 4.9 m (16 ft) and contains two parallel louver arrays that span the channel's entire 2.4 m (8 ft) width. Similar to the primary louvers, both secondary louver arrays are angled 15° to the flow. The anterior louver array in the secondary channel ends in a rectangular opening. This steel "bypass" is 15.3 cm (6 in) in width. However, this is not a bypass to a holding tank; the steel ends 1.7 m (5.6 ft) in front of the posterior louver array's true bypass (width = 15.3 cm (6 in). A fish could be "bypassed" by the anterior secondary louver array and potentially swim through the posterior secondary louver array and be transported into the Delta Mendota Canal.

Each louver array consists of a series of vertical slats each 2.3 cm (0.9 in) apart. The louver slats create a visual and turbulent barrier to fish. Most fish swim against the current but are eventually transported downstream. When a fish encounters the louver array it tends to swim laterally away from the turbulence into the more laminar flow. Thus, fish are "guided" toward the bypass. When a fish goes into the secondary bypass and enters the holding tank, that fish is considered salvaged.

I propose to use acoustic telemetry to evaluate Chinook salmon PSL and WFE. I propose to deploy an acoustic telemetry array, insert acoustic transmitters in Chinook salmon and release these telemetered fish immediately behind the trashrack. The releases shall occur: (1) before a predator removal in the primary channel and (2) after the predator removal in the primary channel. Twenty striped bass will also be captured and acoustic transmitters surgically implanted. I will determine two-dimensional (2D) or three-dimensional (3D) tracks for the Chinook and striped bass. These data will be used to calculate PSL and understand the role of predation in PSL. While sample size will be small, secondary louver efficiency (SLE) can also be calculated using the telemetered Chinook that will be released in the primary channel. But this SLE estimate cannot be considered a truly independent observation; Chinook successfully louvered in the primary channel might be more likely to be louvered in the secondary channel as well.

Previous Research

Since no 2D tracks have ever been determined at the TFCF; I can only report accomplishments of the 2D tracking at the Old River Barrier (ORB). The ORB is a non-physical barrier around which our team deployed an acoustic telemetry system in 2009 and 2010. In both deployments, we were able to determine 2D tracks in real time for Chinook smolts passing by the ORB. Through careful hydrophone placement, system

tuning, and post-processing data we achieved precision of locations estimated at less than 1 m (S. Johnston, personal communication).

Work at the TFCF prior to 2004 (Bowen *et al.* 2004) showed that insertion experiments were more effective at determining factors influencing efficiency than empirical observation (wild fish entering the TFCF with an uncontrollable time schedule). So, I propose to conduct insertion experiments with Chinook salmon to allow me to apply this experimental protocol to Chinook salmon PSL at two predation levels (normal and after predator removal in the primary channel).

Problem Statement

Tracy Fish Collection Facility WFE for Chinook salmon is well studied but PSL is unknown. The Central Valley Project and State Water Project diversions can result in Chinook salmon mortality. I will calculate PSL and I will demonstrate if regular predator reduction in the primary channel could lead to increased survival of Chinook salmon smolts.

Goals and Hypotheses

Goals:

1. Determine Chinook salmon Pre-Screen Loss (PSL).

2. Determine Chinook salmon PSL after a predator reduction in the primary channel.

3. Test a predator reduction methodology in the primary to determine its efficacy.

Hypotheses:

1. The removal of predators in the primary channel will decrease Chinook salmon PSL.

2. The removal of predators in the primary channel will increase Chinook salmon whole facility efficiency.

3. The predator reduction methodology I test in the primary will reduce PSL to ten percent or less.

Materials and Methods

Acoustic Telemetry System

The Hydroacoustic Technology Inc. (HTI) produced acoustic tag tracking system consists of acoustic tags implanted in fish, hydrophones deployed underwater (locations described above), an onshore receiver (HTI Model 290), hydrophone cables that connect the hydrophones and the onshore receiver, and a data storage computer. There are two principal types of deployments: (1) hydrophone arrays, *e.g.,* four hydrophones will form the array in the primary channel and (2) single hydrophones that detect a tag passing by a location.

In this section I describe the hydrophone array and how they generate two-dimensional positions. Each acoustic tag transmits an underwater sound signal or acoustic "ping" that sends identification information about the tagged fish to hydrophones. By comparing the time of arrival of the sound signal at multiple hydrophones, the two dimensional (or if sufficient depth exists to allow sufficient hydrophone separation in the z dimension, the three dimensional) position of the tagged fish can be calculated. The algorithm I use to determine the three dimensional tag position from the measured time delays minimizes the following equation:

$$\sum_{\substack{i,j=1 \\ i \neq j}}^{4} \left[(t_i - t_j) - \frac{1}{c} \sqrt{(h_{ix} - F_x)^2 + (h_{iy} - F_y)^2 + (h_{iz} - F_z)^2} - \sqrt{(h_{jx} - F_x)^2 + (h_{jy} - F_y)^2 + h_j z - F_z)^2} \right]^2$$

where:
t = arrival time of a tag signal on a given hydrophone,
c = speed of sound in water,
h = hydrophone position in each dimension, and
F = tag position in each dimension.

Because of the depth in the secondary, I will not be able to obtain 3D positions there. But, I will attempt to generate 3D tracks in the primary channel. I must wait until I know the depth of and the details of the deployment of the hydrophones to see if sufficient separation can be achieved to obtain 3D tracks. In order to use the system for two dimensional tracking, the above equation is simplified to include only the X and Y dimensions, and uses time delays from only three hydrophones. The HTI AcousticTag data collection and analysis software program allows the user to select between two or three dimensional tag tracking.

Individual tag positions are then assembled in time order to form a track representing the movement of the fish as it passed through the array. This process can be done from stored arrival time data (from Raw Acoustic Tag, or .RAT files), or in real time through the AcousticTag program. And within the outline of the four hydrophones, the resolution should be approximately 1 m.

The four-hydrophone arrays will be adjusted until optimal coverage is achieved. Our goal will be to provide the best achievable coverage of the experimental area while maximizing our ability to determine the fate of each tagged Chinook salmon: (1) swam upstream and out of the TFCF, (2) was salvaged into a holding tank, (3) moved downstream of the TFCF into the Delta Mendota Canal, (4) was eaten by a predator, or (5) there was insufficient data to determine fate.

Data Generation and Protocol

When I release acoustically tagged fish immediately behind the trashrack, I can generate a large diversity of data: (1) I can estimate PSL. (2) I can estimate WFE. (3) I

can and will estimate secondary louver efficiency (SLE). As part of the deployment, I propose to deploy multiple-hydrophone arrays, and produce 2D or 3D tracks, in the following locations: (1) in the primary channel, (2) in the secondary channel upstream of the louvers, and (3) in the secondary channel downstream of the louvers. Also, as part of the deployment, I propose to deploy single-hydrophones: (1) upstream of the trashrack, (2) downstream of the primary channel in the Delta Mendota Canal, (3) in between the two louver arrays in the secondary channel, and (4) in the holding tank. These last four hydrophone positions were selected because of the work of Bark *et al.* (In Preparation).

I will attempt to maintain constant approach channel velocities (ACV) and primary bypass ratios (>1.0) in the primary channel during these experiments. The number of pumps at the Jones Pumping Plant will determine the range of possible ACVs.

The experimental protocol will be:

1. Raise Chinook salmon juveniles to 100 mm TL by March 13.
2. Collect, by March 6, twenty striped bass (range of TL: 50–120 cm):
    a. by hook and line (16 in primary channel)
    b. by dewatering the secondary channel (4 in secondary channel).
3. March 7, surgically implant 10 acoustic transmitters in striped bass (HTI Model 795 LG, 4.5 g weight in air).
4. Hold these 10 surgically implanted fish for 7 d. Feed them daily with live fish prey and observe their behavior pattern. Insure all 10 fish are eating live prey before releasing these predators.
5. March 14, release eight telemetered striped bass in the primary channel and release two in the secondary channel.
6. March 14, surgically implant 20 Chinook salmon smolts (HTI Model 800, 0.5 g weight in air) with acoustic transmitters. Hold these fish 24 h in Delta water to recover from surgical stress (SJRGA 2010).
7. March 15, release 20 Chinook smolts immediately behind the trashrack (Replicate PSL1).
8. March 16, surgically implant 20 Chinook salmon smolts with acoustic transmitters. Hold these fish 24 h in Delta water.
9. March 17, release 20 Chinook smolts immediately behind the trashrack (Replicate PSL2).
10. March 18, surgically implant 20 Chinook salmon smolts with acoustic transmitters. Hold these fish 24 h in Delta water.
11. March 19, release 20 Chinook smolts immediately behind the trashrack (Replicate PSL3).
12. March 14–22, track telemetered Chinook smolts and striped bass.
13. March 18 surgically implant 10 acoustic transmitters in striped bass (HTI Model 795 LG, 4.5 g weight in air). Using 10 remaining striped bass collected, by March 6:
    a. by hook and line (8 in primary channel)
    b. by dewatering the secondary channel (2 in secondary channel).

14. Hold these 10 surgically implanted fish for 7 d. Feed them daily with live fish prey and observe their behavior pattern. Insure all 10 fish are eating live prey before releasing these predators.
15. March 23–24, conduct predator removals in the primary and secondary channels. Methodology to be selected by meetings with NMFS and USFWS. Methodologies to be discussed: electricity, gill netting, and hook and line.
16. March 25, release eight telemetered striped bass in the primary channel and release two in the secondary channel. Surgically implant 20 Chinook salmon smolts with acoustic transmitters. Hold these fish 24 h in Delta water.
17. March 26, release 20 Chinook smolts immediately behind the trashrack (Replicate Predator Reduction (PR)1).
18. March 27, surgically implant 20 Chinook salmon smolts with acoustic transmitters. Hold these fish 24 h in Delta water.
19. March 17, release 20 Chinook smolts immediately behind the trashrack (Replicate PR2).
20. March 18 surgically implant 20 Chinook salmon smolts with acoustic transmitters. Hold these fish 24 h in Delta water.
21. March 19, release 20 Chinook smolts immediately behind the trashrack (Replicate PR3).
22. March 26–April 2, track telemetered Chinook smolts and striped bass.

Statistical Analysis

I described an experimental protocol above that outlines the release of three groups of Chinook juveniles before predator removal and three groups after predator removal. This number of releases with 20 fish per release may not provide sufficient power to resolve our hypothesis (*e.g.*, Hypothesis 1). However, it is uncertain how many more releases would be required to reach an acceptable power (*e.g.*, 0.8). I will use the results of these six trials to determine the standard deviation in these data. The estimate of standard deviation can be used to subsequently estimate sample size (replicates) needed to resolve the hypothesis. Without standard deviation estimates before the experiment, I chose a small number of replicates. This small number, three replicates for each treatment (before and after predator removal), provides an estimate of standard deviation while reducing the overall cost of the project.

Once the data have been collected, we will evaluate these data to determine if they meet the assumptions of Analysis of Variance: independence of observation, normality, and homogeneity of variance. If data meet these assumptions we will use a one-way factorial design. The independent variable will be predator removal. The dependent variable will be whole facility efficiency.

If the data do not meet the assumptions required of ANOVA, we will rely on non-parametric techniques, *e.g.*, Kruskal-Wallis.

Collaboration and Coordination

Final aspects of this study will be coordinated with the TFFIP manager and research coordinator, and Tracy Series editor. Participation and inclusion of research-related updates will be provided to the Tracy Technical Advisory Team (TTAT) and the Central Valley Fish Facilities Review Team (CVFFRT) upon request.

The selection of predator removal methodologies will take place with the National Marine Fisheries Service (NMFS). Appropriate permits will be obtained from NMFS and the U.S. Fish and Wildlife Service (USFWS) for predator removal methods.

Endangered Species Issues, "Take" Considerations

The predator removal methods (gill net, electricity, hook and line) will be evaluated for probability of take of listed species. I will discuss with NMFS and the USFWS the relative tradeoff of potential gains in Chinook salmon survival versus take of listed fishes. If these regulatory agencies believe the potential gains are worth the risk then I will obtain special permits for take for this specific experimental procedure.

Dissemination of Results (Outcomes and Deliverables)

At the completion of these experiments, a Tracy Technical Report will be generated. At time of writing, I am uncertain if I will do this experiment in subsequent years to improve our sample size. If I do this in subsequent years then in this first year I will present the results at one scientific meeting to be determined later. The final report will be generated in the last funded year.

Literature Cited

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Option 2

In 2010, it is possible to conduct only three replicates of pre-screen loss (PSS) and whole facility efficiency (WFE) estimation (20 chinook × 3 replicates = 60 tags in Chinook; 20 tags in striped bass). If I do not conduct the predator removal in 2010, I can tailor our acoustic telemetry system for estimating pre-screen loss and conduct the PSL and WFE experiments. Also during FY 2011, I can work on tailoring the predator removal techniques. Then in FY 2012, I can conduct the full PSL and WFE estimation with predator removal treatment. In this manner, I can reduce our FY 2011 cost and spread the costs over 2 years. Here then, I submit a reduced budget for FY 2011 using this second option.